WATER QUALITY FUNCTION OF RIPARIAN ECOSYSTEMS IN GEORGIA

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Abstract. Riparian ecosystems, particularly riparian forests consisting of mature trees, are now widely acknowledged to have beneficial effects on stream water quality by reducing nonpoint source pollution from agricultural landscapes. This paper presents a summary of recent supporting research findings in the Coastal Plain of Georgia.

INTRODUCTION

Riparian forests in the eastern United States compose a set of ecosystems which have been shown to serve three important ecosystem functions. Lowrance and Vellidis (1994) summarized these functions as the water quality function, the life support function, and the hydrologic function.

Water quality function. By functioning as pollutant sinks, riparian forests provide direct improvement of water quality by keeping pollutants derived from adjacent land uses out of streams or by removing pollutants which entered upstream. This water quality function is due to a number of processes including uptake of nutrients by vegetation; loss of nitrogen to the atmosphere via denitrification; deposition of sediment and sediment borne pollutants; sequestering of pollutants in high organic matter soils; and retention of nutrients due to groundwater storage in alluvial aquifers and surface water storage in swamps. Studies conducted in a number of states including Rhode Island, Maryland, North Carolina, and Georgia (Lowrance et al., 1995; Groffman et al., 1992; Jacobs and Gilliam 1985; Peterjohn and Correll 1984) show riparian forests to be important sinks for nonpoint source pollution.

Life support function. In addition to the removal of pollutants, riparian forests influence stream water quality through direct inputs of detritus to streams; shading of stream channels which controls both light availability and stream temperature; and stabilization of stream banks and channels, reducing channel derived sediments (Karr and Schlosser 1978, Welsch 1991).

Hydrologic function. Riparian forests also play an important role in the hydrology of agricultural landscapes by reducing flood discharge, desynchronizing peak flows, influencing base flow, and modifying groundwater interactions with surface water (Lowrance and Vellidis, 1994; Preston and Bedford, 1988).

Because of these findings, riparian forest buffer systems are accepted by the USDA-Natural Resources Conservation Service as a practice to control pollutant transport when most pollutant movement is in shallow ground water and diffuse overland flow (NRCS, 1996). These conditions are common in much of the Gulf-Atlantic Coastal Plain. The USDA-Forest Service has also developed standards for a specification riparian forest buffer (Welsch, 1991).

Purpose. This paper will summarize research addressing the water quality function of riparian forests in the Coastal Plain of Georgia and focus on the findings of two long-term studies. The following paper in the proceedings by Pringle et al. will summarize research addressing the life support function of riparian forests.

BACKGROUND

The vast majority of production agriculture in Georgia takes place in the Coastal Plain which is dominated by the Tifton-Vidalia Upland (TVU), a physiographic subprovince of the Gulf-Atlantic Coastal Plain. The TVU has relatively homogeneous geology, soils, parent materials, land use, and agricultural management. The TVU includes all or most of 28 counties and parts of 16 others in Georgia (Figure 1), an area approximately 52,000 km^2.

Because of both a plinthic soil horizon and the presence of a geologic formation (Hawthorn Formation) which limits deep recharge to the regional aquifer system, most of the excess precipitation in the TVU move either laterally in shallow saturated and unsaturated flow or moves in surface runoff during storm events. As a result, the TVU contains a dense dendritic network of stream channels bordered by riparian forests.

Figure 1. The Tifton-Vidalia Upland.

RESEARCH FINDINGS

Gibbs Farm Riparian Forest Management Project

A mixed hardwood/pine riparian forest on a second order stream is the site of an experiment on the effects of riparian forest management on agrichemical transport and soil ecological processes. The general hydrology of the TVU is reflected at the Gibbs Farm and was described by Bosch et. al (1996). The riparian forest is part of a Riparian Forest Buffer System (RFBS) which conforms to specifications issued by USDA-FS (Welsch, 1991). The buffer system consists of three concentric zones around the stream.

Zone 1. A narrow band of vegetation which includes the entire stream channel system. This zone ranges from 8-12 m wide and includes typical bottomland hardwood species including yellow poplar, sweet bay magnolia, red maple, and swamp tupelo.

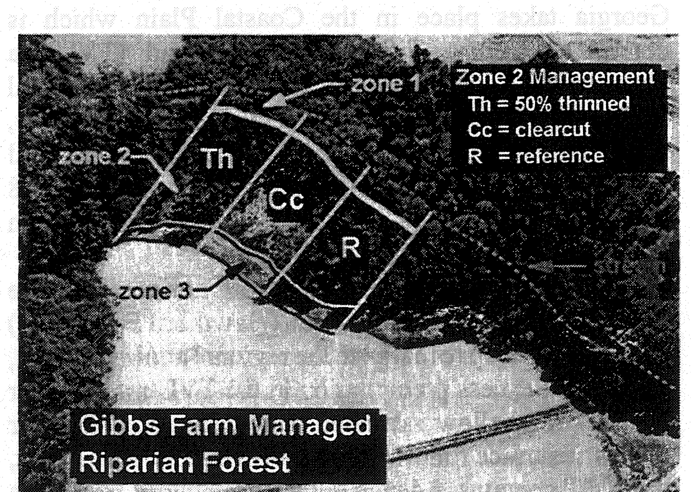

Figure 2. Aerial photo of the Gibbs Farm study site showing the RFBS and the Zone 2 treatment blocks.

Zone 2. A mixed pine/hardwood stand with slash pine, longleaf pine, yellow, wax myrtle, and water between 40 and 55 m wide. Zones 1 and 2 are typical of the riparian forests along first, second and third order streams in the TVU although most Zone 2 areas would be dominated by slash pine. Most of Zone 2 is rarely inundated.

Zone 3. An 8 m grass buffer strip between the field and the forest. Zone 3 was graded to provide uniform surface runoff into the riparian forest.

In early November 1992, one block of Zone 2 forest was clear-cut and one block was selectively cut. A third Zone 2 forest block was left as a reference area (Figure 2). The 2.5 ha field above the buffer system was in continuous corn, grown using conventional production practices for the region, for three years. The crop received N and P applications and atrazine and alachlor were broadcast sprayed from a tank mix during March each year at the recommended rates of 2.85 kg/ha active ingredient atrazine and 3.42 kg/ha active ingredient alachlor (Lowrance et al. 1997).

Instrumentation. A network of 115 shallow ground water monitoring wells and 12 surface runoff collectors were installed to monitor surface and ground water. Wells were installed in transects to track shallow ground water movement from the field to the stream. Surface runoff was collected at the upslope edge of Zones 1, 2 and 3 and at the mid-point of Zone 2.

Surface runoff movement of herbicides. Herbicide concentrations and loads were reduced significantly during transit through the RFBS. Average field edge concentrations were reduced by over an order of magnitude for atrazine and by a factor of about six for alachlor. Relative load reductions were slightly greater than relative concentration reductions. Movement of the two herbicides in surface runoff occurred by June 30 or with the first 25 cm of rainfall that occurred after application (Figure 3). During this period of higher herbicide transport, atrazine and alachlor concentrations averaging 34.1 μg/L and 9.1 μg/L at the field edge, respectively, were reduced to 1 μg/L or less as runoff neared the stream. The effects of Zone 2 management were negligible. Details of the runoff study were presented by Lowrance et al. (1997).

Herbicides in shallow groundwater. There was only minor transport of herbicides through the buffer system in shallow groundwater and little difference between Zone 2 treatment areas. In 1992 and 1993,

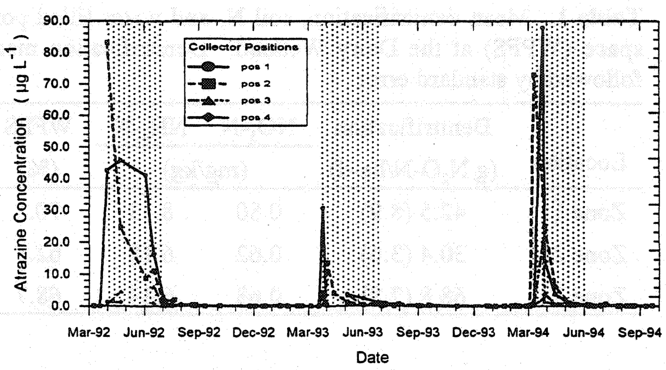

Figure 3. Atrazine concentrations in surface runoff at four positions in the riparian forest at the Gibbs Farm.

herbicide concentrations in shallow groundwater in the RFBS and at the edge-of-field were generally at or below detection limits. In 1994, well concentrations of both herbicides increased, probably in response to infiltration of surface runoff containing high herbicide concentrations. Average herbicide concentrations were at or below detection limits in groundwater near the stream for most of 1994. Details of the groundwater study were presented by Lowrance et al. (1997).

Much of the nutrient transport, denitrification rate, microbial biomass, and fine root biomass data collected from this site are in the analysis and publication stage and will be available shortly.

Dairy Wetland Restoration Project

The second long-term study site is a 0.92 ha restored riparian forest wetland directly downslope from an animal waste land application site receiving liquid manure at a rate of 600 kg N/ha-yr. A 1.5-ha section of the land application site on the west and south sides of the wetland and a 0.7 ha conventionally fertilized pasture on the east side of the wetland drain downslope directly into the wetland (Figure 4). Surface runoff and groundwater from the these uplands flows through the wetland, to the first order stream which drains the wetland, and discharges into a constructed farm pond. During the winter and early spring months when the soil profile is often saturated, runoff events are frequent, and seeps on the southern perimeter of the wetland feed the first order stream. In the summer and autumn, surface runoff generally occurs only during intense rainfall events.

Restoration. The site was clearcut in 1985 and partially restored in February 1991 by reestablishing a combination of native trees and grasses as specified by the three-zone RFBS. Zone 1 was planted to tulip poplar, swamp black gum, and green. Slash pine were planted in Zone 2, which consists of the upslope, rarely inundated, portions of the wetland. Because of the

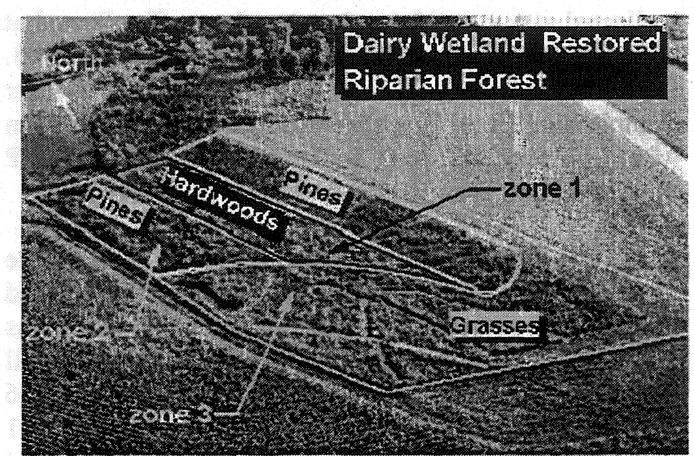

Figure 4. The Dairy Wetland study site showing the RFBS restoration scheme.

already established sod-based production systems in the upland areas, no Zone 3 grasses were planted. The south end of the Dairy Wetland was not replanted to trees because it is under the overhang of the liquid manure application center pivot. Native grasses were allowed to reestablish themselves there and considered part of Zone 3. Liquid manure is applied to the wetland only indirectly as spray drift. The site and restoration efforts are described in detail by Vellidis et al. (1993).

Instrumentation. Networks of shallow groundwater wells and surface runoff collectors are being used to monitor nutrient concentrations and nutrient assimilation as surface and ground water moves through the wetland. Between 1991 and 1997, runoff was sampled at two locations entering the wetland and at two locations near the stream flow.

Nutrients in surface runoff. Runoff collectors were paired to provide data on nutrient retention by the soil and vegetation as surface runoff from the land application site migrated through the wetland. Figure 5 shows PO_4-P concentration changes between runoff

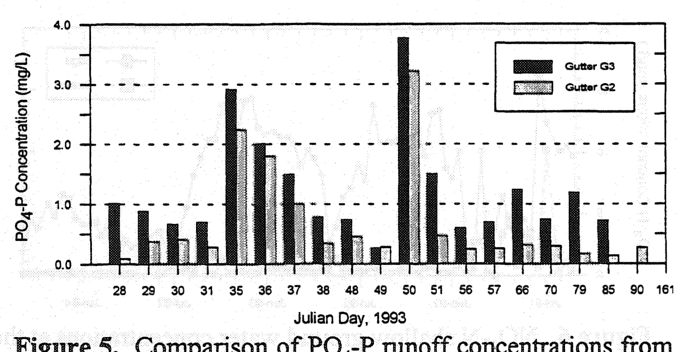

Figure 5. Comparison of PO_4-P runoff concentrations from collection gutters G3 and G2.

collected at gutter G3 (upslope) and runoff collected at gutter G2 (downslope) during February and March, 1993. The bars denote PO_4-P concentrations of composite water samples collected during the indicated day and show an observable reduction in surface runoff PO_4-P concentrations between the perimeter of the wetland.

Nutrients in shallow groundwater. To evaluate attenuation as manure-derived nutrient plumes progressed through the wetland, we compared mean concentrations of wells along the field-edge of the wetland to well concentrations along the wetland stream. Figure 6 presents ground water concentrations from May 1991 through April 1994. With the exception of the first months following restoration, field-edge NO_3-N concentrations were consistently higher than those near the stream with mean concentrations of 8.15 mg/L and 0.92 mg/L, respectively. Mean nitrate/chloride ratios for the 3-year period were 0.26 and 0.02 for edge and stream wells, respectively, indicating that the observed attenuation was not a result of dilution. No significant changes were observed in ground water concentrations of NH_4-N and PO_4-P.

Denitrification. Denitrification was measured monthly using the acetylene inhibition technique on intact soil cores for two months before manure application began on the upland field and for 24 months afterwards. The average annual denitrification rate was 68 kg N_2O-N/ha-yr. Denitrification was significantly higher in the grassed area (Zone 3) on the south side of the Dairy Wetland than in either the Zone 1 (hardwood) or Zone 2 (pines) forested areas (Table 1). Denitrification did not differ significantly between hardwood and pine areas. Denitrification was greater than a conservative estimate of groundwater input of total N. Denitrification rates were higher in April and May 1992 and 1993, after manure application began in the upland, compared to April and May 1991, before manure application began. Complete results are presented by Lowrance et al. (1995)

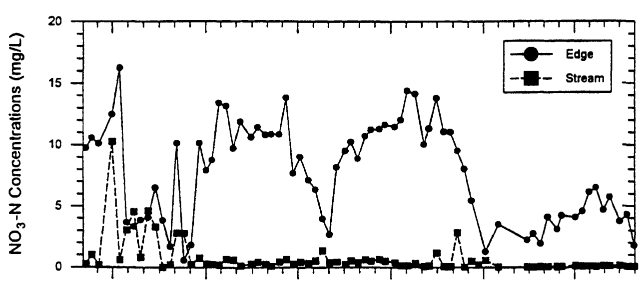

Figure 6. NO_3-N shallow ground water concentrations at the wetland/field edge and near the stream.

Table 1. Mean denitrification, soil N, and water-filled pore space (WPFS) at the Dairy Wetland. Denitrification mean followed by standard error.

Location	Denitrification (g N_2O-N/ha-d)	NO_3-N (mg/kg)	NH_4-N	WFPS (%)
Zone 1	42.5 (8.9)	0.80	8.13	70.3
Zone 2	30.4 (3.6)	0.62	6.18	62.8
Zone 3	68.8 (7.8)	0.63	6.34	68.7

LITERATURE CITED

Bosch, D.D., J.M. Sheridan, R.R. Lowrance. 1996. Hydraulic gradients and lfow rates of a shallow coastal plain aquifer in a forested riparian buffer. *Transactions of the ASAE* 39(6):865-871.

Groffman, P.M., A.J. Gold, R.C. Simmons. 1992. Nitrate dynamics in riparian forests: Microbial studies. *J. Environ. Qual.* 21:666-671.

Jacobs, T.C. and J.W. Gilliam. 1985. Riparian losses of nitrate from agricultural drainage waters. *Journal of Environmental Quality* 14:472-478.

Karr, J.R. and I.J. Schlosser. 1978. Water resources and the land water interface. *Science* 20(1):229-234.

Lowrance, R., G. Vellidis, R.D. Wauchope, P. Gay, and D.D. Bosch. 1997. Herbicide transport in a riparian forest buffer system in the coastal plain of Georgia. *Transactions of the ASAE* 40(4):1047-1057.

Lowrance, R. G. Vellidis, and R.K. Hubbard. 1995. Denitrification in a restored riparian forest wetland. *J. Environ. Qual.* 24(5):808-815.

Lowrance, R. and G. Vellidis. 1994. A conceptual model for assessing ecological risk to water quality function of bottomland hardwood forests. *Environmental Management* 19(2):239-258.

NRCS. 1996. Model national specification for riparian forest buffers. Watershed Science Institute, USDA-NRCS, Seattle, WA.

Peterjohn, W.T., and D.L. Correll. 1984. Nutrient dynamics in an agricultural watershed: Observations on the role of a riparian forest. *Ecology* 65(5):1466-1475.

Preston, E.M. and B.L. Bedford. 1988. Evaluating cumulative effects on wetland functions: A conceptual overview and generic framework. *Environmental Management* 12:565-583.

Vellidis, G., R.R. Lowrance, M.C. Smith, and R.K. Hubbard. 1993. Methods to assess the water quality impact of a restored riparian wetland. *J. of Soil & Water Conservation* 48(3):223-230.

Welsch, D.J. 1991. Riparian forest buffers. USDA-Forest Service, Publication No. NA-PR-07-91.